The absolute chronology of Boker Tachtit (Israel) and implications for the Middle to Upper Paleolithic transition in the Levant

Elisabetta Boaretto[a,b,1], Marion Hernandez[c], Mae Goder-Goldberger[a,d], Vera Aldeias[c,e], Lior Regev[a], Valentina Caracuta[a,f], Shannon P. McPherron[c], Jean-Jacques Hublin[a,c,g], Steve Weiner[a,h], and Omry Barzilai[a,i,1]

[a]Max Planck-Weizmann Center for Integrative Archaeology and Anthropology, Weizmann Institute of Science, 7610001 Rehovot, Israel; [b]Dangoor Research Accelerator Mass Spectrometry Laboratory, Weizmann Institute of Science, 7610001 Rehovot, Israel; [c]Department of Human Evolution, Max Planck Institute for Evolutionary Anthropology, D-04103 Leipzig, Germany; [d]Department of Bible, Archaeology and the Ancient Near East, Ben-Gurion University of the Negev, 84105 Beer-Sheva, Israel; [e]Interdisciplinary Center for Archaeology and the Evolution of Human Behavior (ICArEHB), Universidade do Algarve, 8005/139 Faro, Portugal; [f]Institute of Evolutionary Sciences of Montpellier, University of Montpellier, 34090 Montpellier, France; [g]Collège de France, 75005 Paris, France; [h]Department of Structural Biology, Weizmann Institute of Science, 7610001 Rehovot, Israel; and [i]Archaeological Research Department, Israel Antiquities Authority, 91004 Jerusalem, Israel

Edited by James F. O'Connell, University of Utah, Salt Lake City, UT, and approved April 14, 2021 (received for review July 16, 2020)

The Initial Upper Paleolithic (IUP) is a crucial lithic assemblage type in the archaeology of southwest Asia because it marks a dramatic shift in hominin populations accompanied by technological changes in material culture. This phase is conventionally divided into two chronocultural phases based on the Boker Tachtit site, central Negev, Israel. While lithic technologies at Boker Tachtit are well defined, showing continuity from one phase to another, the absolute chronology is poorly resolved because the radiocarbon method used had a large uncertainty. Nevertheless, Boker Tachtit is considered to be the origin of the succeeding Early Upper Paleolithic Ahmarian tradition that dates in the Negev to ∼42,000 y ago (42 ka). Here, we provide ^{14}C and optically stimulated luminescence dates obtained from a recent excavation of Boker Tachtit. The new dates show that the early phase at Boker Tachtit, the Emirian, dates to 50 through 49 ka, while the late phase dates to 47.3 ka and ends by 44.3 ka. These results show that the IUP started in the Levant during the final stages of the Late Middle Paleolithic some 50,000 y ago. The later IUP phase in the Negev chronologically overlaps with the Early Upper Paleolithic Ahmarian of the Mediterranean woodland region between 47 and 44 ka. We conclude that Boker Tachtit is the earliest manifestation of the IUP in Eurasia. The study shows that distinguishing the chronology of the IUP from the Late Middle Paleolithic, as well as from the Early Upper Paleolithic, is much more complex than previously thought.

MP to UP transition | Initial Upper Paleolithic | Emirian | Boker Tachtit | Southern Levant

The spread of modern humans from Africa into Eurasia is certainly one of the most important events in human history (1–3). The appearance of *Homo sapiens* at the transition between the Middle Paleolithic (MP) and the Upper Paleolithic (UP) periods corresponds with the demise of Neanderthals in Europe and west Asia (4). This demographic process, known in the literature as the "Recent African Origin" (5), has undergone refinements since it was first introduced (6). Today, this dispersal event is thought to be a multifaceted process that involved several events and genetic admixture between *H. sapiens* and Neanderthals (7–12).

Recognizing demographic changes in the archaeological record is not always straightforward, mainly because of a lack of human fossils. Still, transformations in material culture are often conceived as a reliable indicator for demographic change (13, 14). In the Levant, as in Europe, such changes occurred during the transition from the MP to the UP, namely, the replacement of Levallois technology by blade technologies and the introduction of systematically produced tools on bone and antler (15–18). The nature and timing of the MP to UP transition has been investigated for almost a century (18–24). While the characteristics of the material culture changes are more or less defined, the absolute chronology and the origins of the transitional industries are under debate (25–30).

One of the major reasons for this uncertainty is the fact that many of the key sites with supposedly "transitional" lithic industries in the south Levant, such as Emireh and el-Wad caves, were excavated in the beginning of the 20th century and their stratigraphies are challenging (24). An important exception is the site of Boker Tachtit in the Negev Highlands, Israel, that comprises a series of intact stratigraphic layers with refitted lithic assemblages, which are separated by sterile sediments (31, 32). Here, we report the results of an excavation at Boker Tachtit and in particular the chronology based on radiocarbon and optically stimulated luminescence (OSL) dates.

Boker Tachtit is located in the Wadi Zin basin in the central Negev region, Israel (Fig. 1). The site was discovered and excavated by A. Marks in the framework of the Central Negev Project (31). The excavation revealed well-preserved archaeological horizons (Levels 1 through 4 from the bottom up) composed of flint artifacts, a few hammer stones, and charcoal pieces, including the presence of a hearth feature in Level 1. Comprehensive lithic studies enabled technological reconstructions of the lithic industries at the

Significance

The Initial Upper Paleolithic (IUP) marks a distinct cultural change possibly related to *Homo sapiens* dispersals into Eurasia. New radiocarbon and optically stimulated luminescence dates from the recent excavations at Boker Tachtit, Negev, Israel, show that the IUP starts as early as around 50,000 y ago, and the later IUP phase dates to 48,000 y ago. Thus, the Late Middle Paleolithic (MP) and early IUP populations both inhabited the Negev 50,000 y ago. The Negev later IUP phase and the Early UP of the Eastern Mediterranean woodland are contemporaneous. These results also show that the MP to UP transition was a fast-evolving process.

Author contributions: E.B., S.P.M., J.-J.H., S.W., and O.B. designed research; E.B., M.H., M.G.-G., V.A., L.R., V.C., S.P.M., J.-J.H., S.W., and O.B. performed research; E.B., M.H., and L.R. contributed new reagents/analytic tools; E.B., M.H., M.G.-G., V.A., L.R., V.C., S.P.M., J.-J.H., S.W., and O.B. analyzed data; and E.B., M.H., M.G.-G., V.A., S.P.M., J.-J.H., S.W., and O.B. wrote the paper.

The authors declare no competing interest.

This article is a PNAS Direct Submission.

[1]To whom correspondence may be addressed. Email: elisabetta.boaretto@weizmann.ac.il or omry@israntique.org.il.

This article contains supporting information online at https://www.pnas.org/lookup/suppl/doi:10.1073/pnas.2014657118/-/DCSupplemental.

Published June 14, 2021.

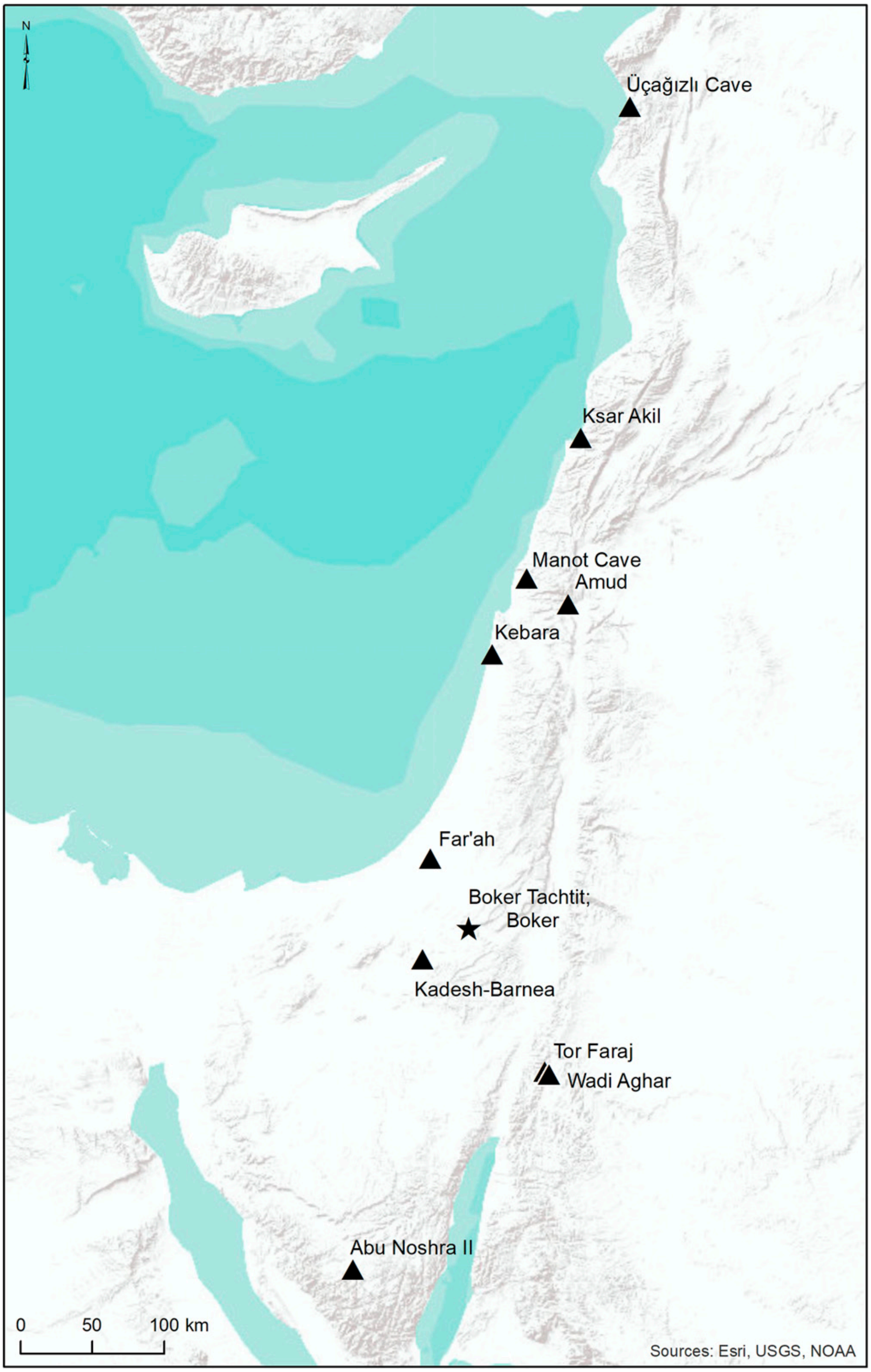

Fig. 1. Location of Boker Tachtit and other sites mentioned in the text.

site as well as spatial aspects of these occupations (32–34). The refitting study demonstrated a technological continuity from the lowermost Level 1 to the uppermost Level 4 and indicated on-site flint knapping. This later point is additionally supported by a study of the microflints from Marks' excavation section D (35). Marks conceived Boker Tachtit as an MP to UP transitional site bearing two consecutive cultural phases: the Emirian (Levels 1 through 3), which he associated with the MP, and the Initial UP (IUP) (Level 4), which was predominantly UP (28). Later studies by Kuhn that included sites in the north Levant redefined the IUP and incorporated the Emirian into this phase (16). In this paper, we follow Kuhn's definition for the IUP.

The original chronology of Boker Tachtit was based on five radiocarbon dates using the ^{14}C decay counting method (31). Four samples (GY-3642, SMU-184, SMU-580, and SMU-259) were from Level 1 and one sample (SMU-579) from Level 4. Two samples were of infinite ages (GY-3642, >33,000 BC; SMU-184, >43,620 BC), and one (SMU-579, 33,105 ± 4,100 BC) appeared to be an outlier. Another (SMU-580, 44,330 ± 9,050 BC) had an extremely wide uncertainty range of 9,000 y. The only supposedly reliable date (SMU-259, 44,980 ± 2,420 BC) was used to set the chronology of the site to ∼47 ka BP. The latter date was perceived by Marks and many others to reflect the age of the MP to UP transition in the Levant (1, 13). The few samples analyzed and the large uncertainties are related to the methodology used and probably also to the quality of the charred material analyzed.

More recent MP to UP chronological studies based on radiocarbon dating of charred material and marine shells from new and old excavations at other sites have initiated a debate about the chronology of the transition, and the age of Boker Tachtit was suggested to be too old compared with northern Levantine sites (25, 27, 29, 30, 36). The problems lie in the disparities in the documented timing of the transition. While these differences may reflect a time lag in the transition between Boker Tachtit and the northern Levantine sites, problems with the quality of dated material or their context should not be overlooked (i.e., stratigraphic provenience and/or diagenesis) (e.g., refs. 25, 29, 30).

New Excavation at Boker Tachtit

New excavations were carried out at the site during 2013 through 2015 (37). The major aim of the project was to more precisely determine the chronological age of the site using advanced ^{14}C and luminescence methods. The excavation focused on sections D and E of the old excavation (ref. 31, figures 2–7, 2–11, and 2–12). The correlation between the present excavation's stratigraphy and that of Marks' excavations, described in detail by Goldberg (38), are discussed in *SI Appendix*, Figs. S1 and S2. Here, we briefly summarize the stratigraphy of the present excavation.

The section has two major lithostratigraphic units; the upper one is composed of bedded gravels (BGs), and the lower one is composed of well-stratified silty sand deposits (SSds) (Fig. 2). A sharp erosional unconformity separates the BGs from the SSds. The archaeological sequence is embedded in the SSds.

Almost all of the lithic artifacts are located within the upper part of the SSds, which is approximately 1 m thick. Some of the layers contain courser gravels and pebbles. The archaeological horizons are slightly dipping by about 10° to the southwest. Based on the original stratigraphy presented in Marks (1983), we identified and excavated two levels: Archaeological Horizon A (AH-A), corresponding to Level 4, and Archaeological Horizon B (AH-B), corresponding to Level 2 (*SI Appendix*, Fig. S1). Levels 1 and 3 were not identified in the current excavation. AH-B was identified in the southern part of the excavation. This level is ∼30 cm thick along the section and, in terms of artifact density distributions, can be divided into a lower and upper portion. The lithic industry recovered from AH-B was analyzed and compared to Marks' Level 2 (*SI Appendix*, Fig. S3). The dominant technology consists of bidirectional and unidirectional blade production using crested blades for core shaping and rejuvenation. Characteristic tools consist of retouched pieces on flake and blade blanks, burins, and points, including an Emireh point (*SI Appendix*, Fig. S3). Conjoined flint artifacts connect the AH-B assemblage to Marks' Level 2, thus confirming the identification of Level 2 (*SI Appendix*, Fig. S3).

AH-A was recognized in most of the section of the current excavation and was excavated in three continuous segments. The northernmost segment corresponds to Marks' section D (*SI Appendix*, Fig. S1). This horizon is composed of a thin exposure of lithic artifacts (2- to 5-cm thick). A small and shallow pit with burnt material was identified in the northern part of the site during excavation and was shown to be intrusive by radiocarbon dating (*SI Appendix*, Figs. S2, S4, and S6). The characteristics of the lithic assemblage are basically the same as described by Marks for Level 4 (*SI Appendix*, Fig. S3). The technology is focused on the production of unidirectional blades from mostly narrow-faced single-platform cores (i.e., pyramidal cores). Characteristic tools include points and scrapers mostly on blade blanks, and notably, no Emireh points are present (*SI Appendix*, Fig. S3).

Radiocarbon Dating Chronology

Only very small individual fragments of wood charcoal were found in the new excavation. These fragments were almost always confined to the archaeological horizons (AH-A; AH-B) and were absent from the archaeological sterile layers in SSds.

The samples collected were at least a millimeter in their longest dimension. The taxonomic affinities of all of the collected samples were determined. They belong to four major species that are typical of semiarid environments: *Pistacia atlantica*, *Juniperus cf phoenicea*, *Tamarix* sp., and *Hammada scoparia* (*SI Appendix*, Fig. S4 and Table S3). The samples selected for radiocarbon dating were from contexts that could be associated with significant flint

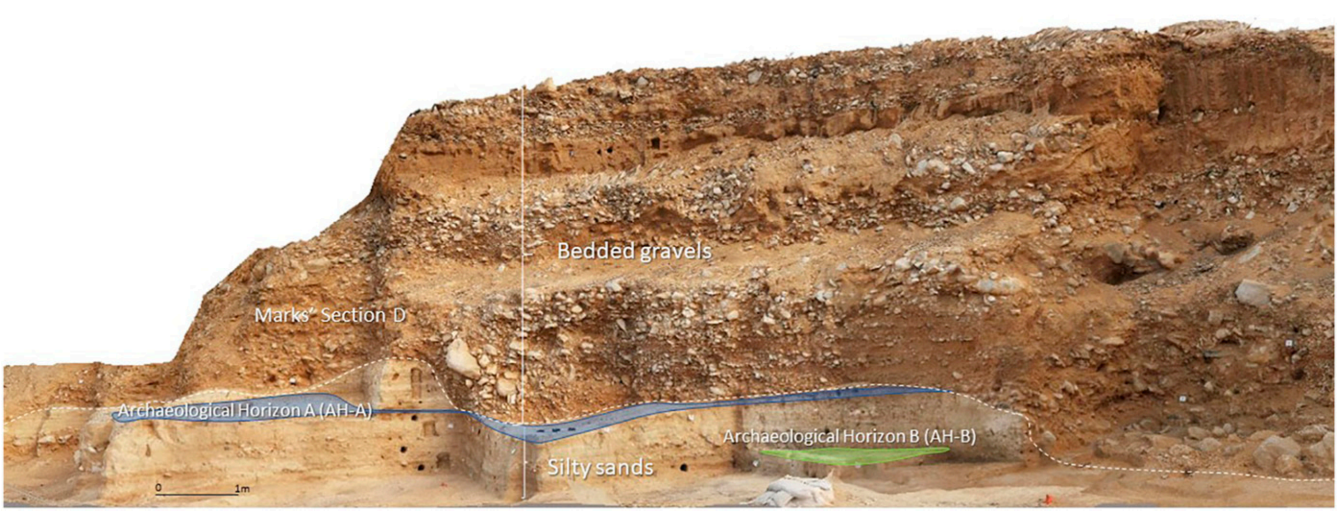

Fig. 2. Boker Tachtit stratigraphic profile of the new excavation (a view to the east). The archaeological horizons, A and B, are embedded within the SSds.

https://doi.org/10.1073/pnas.2014657118

concentrations. We preferably analyzed individual charcoal fragments, but in a few cases, we had to combine small fragments from the same locus and the same species. Note that, in a few cases, we deliberately dated charcoals from dubious contexts, such as the pit from AH-A, in order to test for the presence of intrusive charcoal (*SI Appendix*, Fig. S4).

The second level of prescreening was carried out in the laboratory. We used Fourier transform infrared spectroscopy (FTIR) to analyze very small parts of the fragments before the cleaning, and we rejected samples that did not produce a well-defined charcoal spectrum or were contaminated with a lot of clay (*SI Appendix*, Fig. S4). FTIR spectra were also obtained after the pretreatment procedure, and samples with appreciable amounts of clay were rejected. In a few cases, we analyzed the radiocarbon concentrations without a second FTIR analysis. We also determined the amount by weight of carbon after the oxidation step and before the graphitization step. Samples with less than 40% weight carbon (Carbon %) were also rejected, as this means that the sample was either diluted by minerals and/or contained relatively large amounts of noncharcoal-like organic matter (not well burnt or humic acid contamination). Note too that many of the samples partially dissolved during the cleaning procedure and insufficient material remained for determining the radiocarbon concentration. The procedure applied to prepare the samples for the accelerator mass spectrometry (AMS) determination followed that of Alex et al. (30) and Rebollo et al. (25). We also rejected three samples that still had clay after the initial preparation procedure, and these were then treated with hydrofluoric acid (HF). These samples, however, were not included because we did not have associated background material to prove that this new procedure does not introduce modern carbon. The complete list of samples analyzed for radiocarbon, including those analyzed for radiocarbon but rejected, is given in *SI Appendix*, Fig. S4 and Table S3.

All radiocarbon dates from Boker Tachtit were calibrated using the new calibration curves IntCal20 based on terrestrial and marine data (39, 40), using the program OxCal version 4.4.2 Bronk Ramsey (2020) (41). Fig. 3*A* shows the plot of all the dates, including the rejected dates. The accepted dates are divided according to the level from which they were derived (AH-B or AH-A) and within each level from the locus in which they were found. Samples from the same locus are arranged according to the radiocarbon date obtained. Fig. 3*B* shows that three samples produced finite calibrated dates that are around 49,000 y calibrated (cal) BP (RTD 7740, 8162, and 8155). Significantly one (RTD 7740) of these dates is from a charcoal fragment in sediments coming from below the AH-B lithics. The other two oldest charcoal samples (RTD 8162 and 8155) were found within 30 cm above the oldest sample and are in association with the lithic artifacts in AH-B (loci 228 and 227, respectively). The calibrated dates for these three old samples range from about 50,600 to 47,600 y cal BP ($\pm1\sigma$). The dates from above AH-B (locus 225) range from 46,100 to 44,300 y cal BP (see *SI Appendix*, Table S3 for context information).

The three samples dated from AH-A produced calibrated dates from around 47,300 to 44,400 y cal BP (see *SI Appendix*, Table S3 for context information). There is clearly an overlap in dates between the AH-A and the upper portion of AH-B (see *SI Appendix*, Table S3 for context information).

Luminescence Dating (OSL) Chronology

In this study, we report the luminescence age results obtained for 10 sediment samples. Three of these samples were from the BG lithostratigraphic unit and seven from the underlying silty sand unit including the archaeological horizons (AH-A and AH-B). All samples were retrieved by hammering opaque plastic tubes into the stratigraphic section.

The K, U, and Th concentrations were determined by high-resolution gamma spectrometry performed on the ends of the sampling tubes. Beta and gamma dose rates were then calculated with the dose rate conversion factors of Guérin et al. (42); moisture correction was performed following Zimmerman (43), and grain size attenuation factors were taken from Guérin et al. (44). The representativeness of those concentration values for the determination of gamma dose rates was checked through a comparison with field gamma measurements (for details on the procedure to determine dose rates determination, see *SI Appendix*, Fig. S5 and Table S4). Both quartz- and feldspar-rich extracts were measured. In both cases, we have selected the dominant grain-size fraction (i.e., 40 to 63 µm).

Several luminescence signals were measured to determine the corresponding equivalent dose (D_e) using a single aliquot regenerative (SAR) dose protocol: Blue OSL on quartz grains (45) and $IRSL_{50}$ (46) and post–IR-$IRSL_{290}$ (47) on feldspar (see details on the protocols in *SI Appendix*, Table S5). For Blue OSL results, the age presented is derived from the arithmetic average D_e calculated on 24 multigrain aliquots per sample following the recommendation in ref. 48 to calculate multigrain OSL ages. Details about the distributions of the D_e results are given in *SI Appendix*, Fig. S5. The $IRSL_{50}$ °C ages were corrected for fading after (46).

Several studies on post–IR-$IRSL_{290}$ signals on feldspar have shown that a residual dose that can be considered as "unbleachable" often leads to an overestimation of post–R-IRSL ages, especially for samples with rather low D_e values (e.g., ref. 49). As a result, we determined the D_e of modern analog samples (11 ± 4 Gy; see details in *SI Appendix*) and calculated two sets of post–IR-$IRSL_{290}$ ages: one with the measured D_e values and one after subtracting the measured residual dose (*SI Appendix*, Table S6). Interestingly, on average, the residual-corrected post–IR-$IRSL_{290}$ ages underestimate the quartz OSL ages (the average ratio of post–IR-$IRSL_{290}$ to OSL is 0.91 ± 0.04), while the uncorrected post–IR-$IRSL_{290}$ ages slightly overestimate the quartz OSL ages (the average ratio is 1.15 ± 0.05), especially for the three samples corresponding to the gravel level (ratio 1.34 ± 0.02, against 1.07 ± 0.05 for the SSds samples). The average $IRSL_{50}$ to quartz OSL age is 0.98 ± 0.03. This issue questions the accuracy of the post–IR-IRSL residual dose measured on the modern analogous samples that should suffer from an incomplete bleaching cycle and so overestimate the unbleachable dose subtracted, especially for the SSd samples (50).

Since the luminescence signals measured are characterized by different bleaching rates (51), from the fastest for Blue OSL to the slowest for post–IR-$IRSL_{290}$, the good correspondence between the ages suggests that all signals were reset prior to sediment deposition and that the samples can be considered as well bleached. In the following, we consider the quartz OSL ages as the most reliable data set because no fading or residual dose corrections are required.

From a chronological point of view, the results show a clear gap of ∼30 ka between the SSds unit and the overlying BG unit, with the latter yielding ages of between 20 and 15 ka and the former yielding ages of between 58 and 42 ka (*SI Appendix*, Table S6 and Fig. 4).

However, considering the luminescence dating uncertainties, it is not possible to identify different chronological phases related to the different archaeological horizons.

Discussion

The Absolute Chronology of Boker Tachtit. The new ^{14}C dates and OSL dates overlap between 50,000 and 44,000 y cal BP. Although this time range covers only 6,000 y, it corresponds to three periods in the Levant: Late MP (LMP), IUP, and Early UP (EUP) (30).

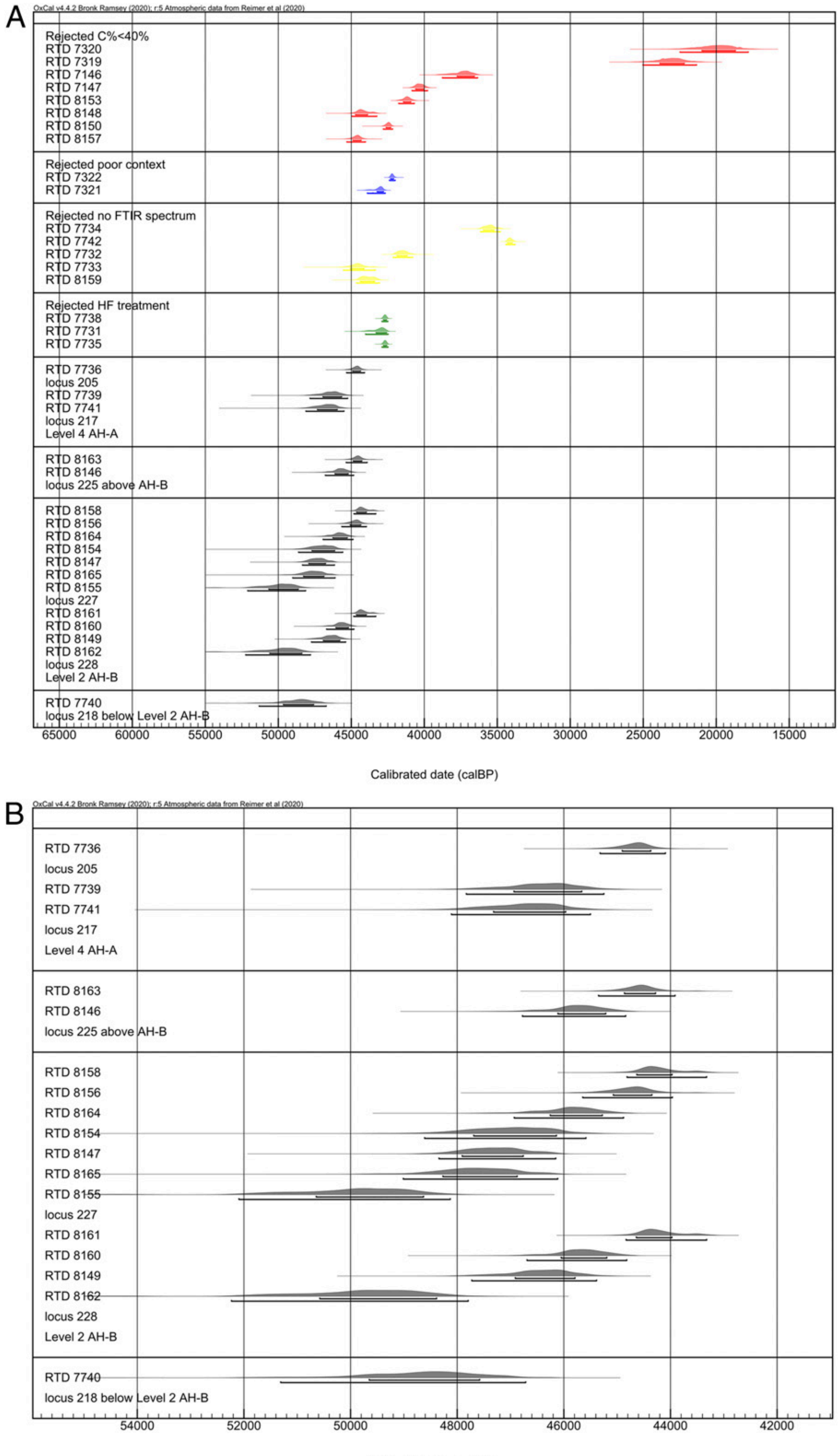

Fig. 3. Radiocarbon dates from Boker Tachtit new excavation. (*A*) Calibrated radiocarbon dates of all the samples analyzed. The samples (RTD 7320 and 7319) below 20,000 y are not plotted to enlarge the time scale. (*B*) Samples that passed the criteria defined in the text. Note that some of the rejected samples overlap with the nonrejected dates, but many are clearly beyond the range in B. The calibration range was determined using the new 2020 Terrestrial calibration curve (39).

Previous and current lithic studies have identified two lithic traditions at Boker Tachtit: the Emirian corresponding to Marks' Levels 1, 2, and 3 (Level 2 corresponds to AH-B current excavation) and the Level 4 industry (AH-A current excavation) originally defined by Marks as IUP, corresponding to Ksar Akil phase A (22, 28, 52). Thus, the challenge is to determine the ages of these two lithic industries and their stratigraphy at high resolution. The OSL uncertainty does not permit a separation between the layers.

https://doi.org/10.1073/pnas.2014657118

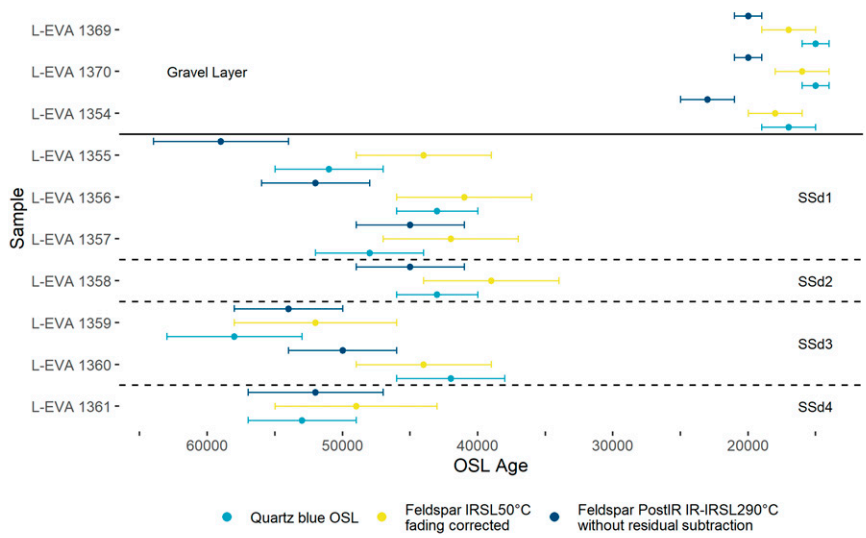

Fig. 4. Luminescence age results of Boker Tachtit. The post–IR-IRSL ages reported in this figure do not take into account the unbleachable residual dose. The $IRSL_{50}$ °C ages presented are given after fading correction (*SI Appendix*, Table S4).

In principle, radiocarbon should be able to differentiate between these two levels because the uncertainty is ±300 to 600 y at this period of time, provided the two levels are totally separated vertically and horizontally. The radiocarbon dates did not, however, differentiate between Levels 2 and 4. The problem is not due to the uncertainties in the radiocarbon measurements or to stratigraphy (see *SI Appendix*, Figs. S4 and S14 *A* and *B* to demonstrate this). The problem rather relates to some aspects of the site formation processes, which must have resulted in a redistribution of some of the charcoal fragments analyzed; therefore, Bayesian modeling will not resolve this issue.

Visually, the SSds' sequence is well stratified, and occupation Level 1 (identified by Marks) and Levels 2 (AH-B) and 4 (AH-A) (identified by Marks and in the current excavation) sequentially overlay each other and are separated by archaeologically sterile sediments, within a section that is less than 1 m thick (*SI Appendix*, Fig. S1 and Fig. 3). There has been postdepositional modification of the sediments that includes differential dissolution of the calcite component with differential compaction of the sediments (*SI Appendix*, Fig. S1). Intrusive features include channels and burrows as well as a rounded pit, presumably a burrow, that clearly intruded into AH-A (Level 4) and contained charcoal dated to around 31,000 cal BP. Still, as noted before, almost no charcoal fragments (and artifacts) were found between AH-B and AH-A (Levels 2 and 4). We therefore do not envisage that vertical mixing could explain radiocarbon age overlapping, except locally because of burrowing.

Radiocarbon dating of charcoal fragments older than around 40,000 y is challenging. The charcoal often dissolves in the strong acid and base solutions needed to stringently remove even the smallest amount of carbonate and organic contamination. We report all the samples dated (Fig. 3), including the ones that we regard as suspect for the following reasons: Carbon % is less than 40%, the contexts are not absolutely clear, there was insufficient material to obtain an FTIR spectrum prior to analyzing the ^{14}C concentration, and samples that required HF treatment to remove clays that may have had their own extraneous organic material. We will now discuss only the nonrejected samples shown in black in Fig. 3*B*.

The total range of the obtained radiocarbon dates is from around 50,000 cal BP to around 44,400 cal BP. The three oldest dates are at the base of the stratigraphy and most probably represent the first occupation of Boker Tachtit. With an age of around 50,000 y BP, the Emirian (AH-B) at Boker Tachtit is the earliest evidence for the appearances of IUP in the Levant. We also note that the very large charcoal sample (SMU 259, 44,980 BC ± 2,420 y) derived from a large hearth in Level 1 of Marks' excavation (31) was dated by Marks et al. and corresponds to a range of 52,500 to 47,100 cal BP (±1σ) using the IntCal 2020 calibration curve (39). This is consistent with the observations reported here.

Unexpectedly, the three dates from AH-A overlap with the AH-B dates in the later part of the range, around 47,000 to 44,000 cal BP, even though the lithic techno-typology of AH-A artifacts are clearly distinguishable from the techno-typology of upper AH-B artifacts. We are unable to unequivocally explain this observation, but we can infer that upper AH-B and AH-A must have been sequentially deposited within a relatively short period of time that ended around 44,000 BP. Bearing in mind the above complexities, we suggest the following chronological reconstruction for the site according to Marks' stratigraphy.

The first occupation dated in this study at Boker Tachtit occurred around 50,000 to 49,000 cal BP, and this corresponds to early AH-B based on the new dates RTD 7740 and RTD 8162 (Fig. 3). These oldest layers contain the Emirian lithic industry. We therefore conclude that the Emirian industry is already present at around 50,000 to 49,000 cal BP. The lithic industry of AH-A, the second phase of the IUP, is dated to around 47,000 cal BP.

The Transition between the MP and UP in the Levant. An examination of absolute chronologies of LMP, IUP, and EUP sites in the region provides an interesting scenario for the MP to UP transition (Fig. 5). Notably, the two phases of Boker Tachtit overlap with the IUP of Wadi Aghar (Layer D2) located in Gebel Qalqha in Jordan, ∼100 km southeast of Boker Tachtit (53). The wide chronological range at Wadi Aghar, which was recently dated (50 ± 3 ka, Layer D2; 45 to 40 ± 3 ka, Layers D1 through C; 39 to 36 ± 3 ka, Layer B), most probably reflects the precision of the OSL method (54). As noted above, the Boker Tachtit OSL age (quartz fraction) ranges between 58 ± 5 ka and 42 ± 4 ka. Overall, the new ages from Boker Tachtit and Wadi Aghar show the IUP in the arid zone started as early as 50 ka.

The radiocarbon ages of the two levels from Boker Tachtit also overlap with the final LMP occupations in the neighboring sites of Far'ah II (western Negev) and Tor Faraj Layer C

(Gebel Qalqha) as well as with the final stages of the LMP at Kebara cave in the Mediterranean woodland region (Fig. 5). The ages from Tor Faraj range from 69 to 44 ka (55). This is a very wide range, and the youngest ages (28 ka and 44 ka) are probably outliers. The ages were made using three dating methods employed 20 y ago (TL, U-Series, and amino acid racemization), hence the wide range. Far'ah II, on the other hand, was recently excavated and dated by radiocarbon and OSL, providing an age of <49 ka (56). Two more LMP occupations in the Mediterranean woodland region, Kebara Cave and Ksar Akil, were also recently dated by radiocarbon (25, 27, 29). The age range of Kebara Cave overlaps with Boker Tachtit, while Ksar Akil LMP is later.

When compared with the EUP (Ahmarian) sites, the IUP shows different trends for the arid and the Mediterranean woodland zones. The later IUP phase at Boker Tachtit (AH-A) is earlier than the EUP Ahmarian sites in the region (i.e., Boker A, Kadesh Barnea, and Abu Noshra), which were dated by the radiocarbon method in the 1980s (Fig. 4). This is consistent with the proposal of Marks that there was a local development of the EUP from the IUP in the Negev. Yet, the age range of the IUP phase at Boker Tachtit overlaps with EUP Ahmarian sites from the Mediterranean woodland region such as Manot and Kebara caves (Fig. 5). We therefore propose that the Mediterranean EUP did not develop from the arid zone IUP. In fact, the EUP Ahmarian may have two geographical variants (and origins): a northern one dating from 47 to 42 ka characterized by bidirectional blade industry and a southern one starting from 43 ka and characterized by unidirectional blade industry (57). This distinction between two geographical facies of Ahmarian is noted also at a later stage (58). We also note that the Boker Tachtit IUP starts much earlier than this phase at Ksar Akil and Üçağızlı (30). These two northern Levantine sites should be attributed on the basis of dates and characteristics of lithic technology to a later phase within the IUP.

Two scenarios have been suggested for the origins of the Boker Tachtit industries: local development and off-regional origin African/Arabian. The local development scenario, proposed by Meignen (26), suggests that IUP technical traits emerged from local LMP groups. This hypothesis does not refute the idea that the technological change could also have been stimulated by populations coming into the Levant during marine isotope stage (MIS) 3. Currently, it is difficult to confirm this hypothesis since there are very few LMP sites predating Boker Tachtit in the Negev that could be compared. The local MP site of Nahal Aqev excavated by Marks was proposed to date to 80 ka based on the age of a close by travertine (59, 60). The site was recently excavated, and OSL dating is underway (61). The Nahal Aqev industry characterized by the centripetal Levallois method does not reflect a possible source for technological continuity (Barzilai personal observation). Rosh Ein Mor, with an LMP industry, including

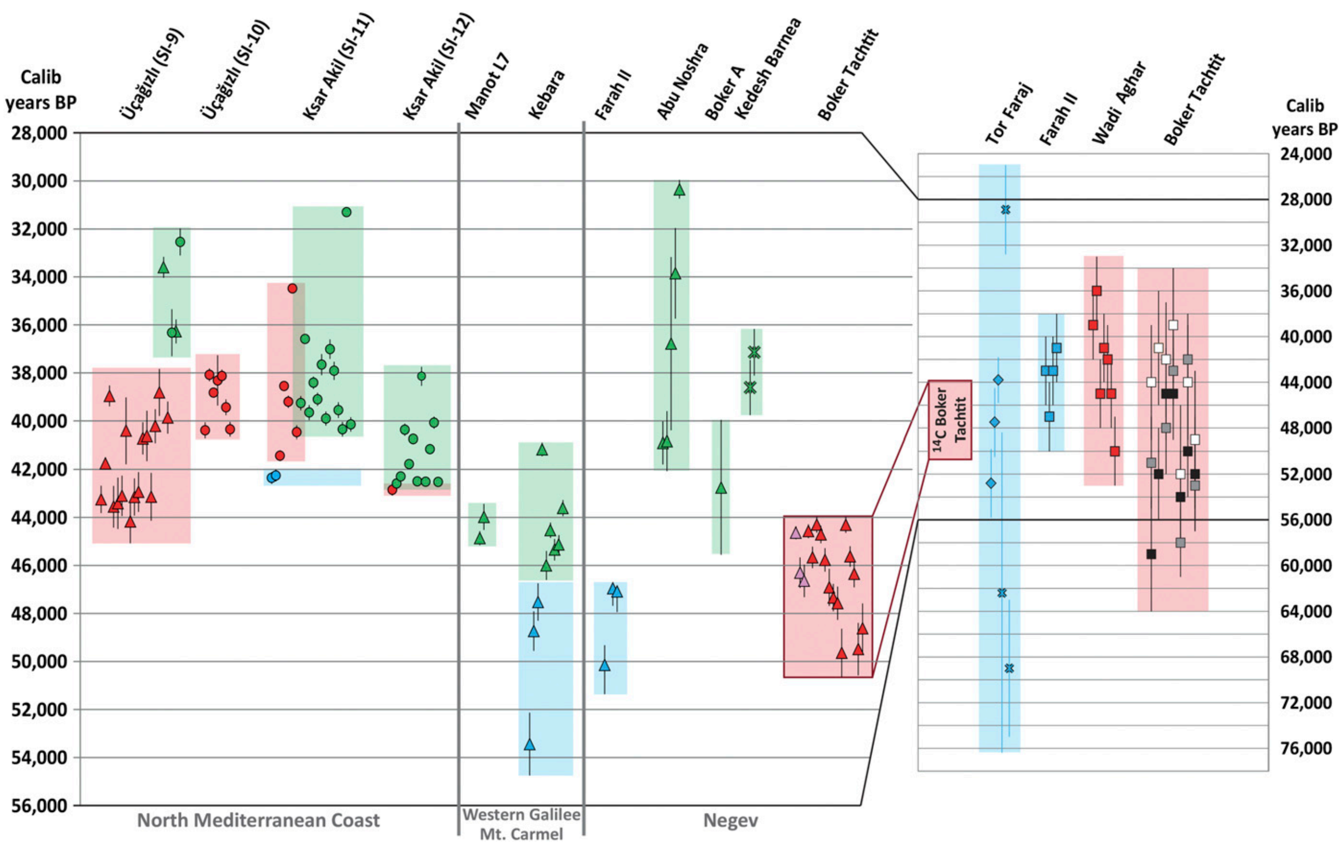

Fig. 5. Dates associated to sites considered for this study. Radiocarbon-based dates are represented as ±1σ (68.2% probability range) calibrated range with the symbol in the middle of the range. The calibration range was determined using the new 2020 Terrestrial calibration curve (39). Radiocarbon-based dates from marine shells have been calibrated with the 2020 Marine calibration curve (40). Triangles are charcoal, circles are shells, squares are OSL-based, diamonds are TL, and crosses are U series and amino acid racemization (AAR). Industries are color coded: blue is Mousterian/LMP, red is IUP, and green is EUP/Ahmarian. The total calibrated ranges are unmodeled and are represented by colored areas and include all the dates presented in the publication. The sites are separated by regions. The right-side plot does not include any radiocarbon dates. The radiocarbon calibrated range obtained for Boker Tachtit is represented as a square in the TL/U series/AAR/OSL dates. Note the different *y*-axis scales between the two plots. Data used in this figure are reported in *SI Appendix*, Table S3. For the Üçağizli and Ksar Akil sites, the references below refer to the list in the *SI Appendix*. For the data set of Radiocarbon Boker Tachtit, the samples from Level 4 are in pink. The Boker Tachtit OSL are separated according to the method: black, post–IR-IRSL; white, quartz; and gray, ISRL fading.

elements of blade production, reflects a wide chronological range most probably representing a palimpsest (62–65).

The off-regional hypothesis may explain the contemporaneity of two different lithic traditions in the Negev around 50,000 y ago (i.e., the LMP industries of Tor Faraj and Far'ah II and the IUP Emirian industry at Boker Tachtit). The recent lithic analyses from Boker Tachtit and Far'ah II have shown similar techno-typological traits between the assemblages, such as the presence of single-platform cores, butt-striking platform preparations, and "Levallois-like" points (64). This may suggest some level of contact between the bearers of the two industries as a clear-cut change in technology is not evident. This coexistence of Levallois technologies with IUP industries, also noted in other regions at the MP/UP interphase (i.e., Bohunician in central Europe and Uluzzian in southern Europe), is an indication for off-regional arrival of hominins (3, 9). This might have been the case for the Negev as well, as proposed previously but without radiocarbon evidence (ref. 28; but see contra ref. 26). The coexistence of Emirian and Late Mousterian could imply that the origins of the Emirian industry are not in this region but may also portray local innovation. We are not aware of sites in the Nile Valley region nor in Arabia that contain the Emirian industry. We do, however, note that these regions may bear potential forbearers for the Emirian industry. In the Nile Valley, it is the Taramsan industry which bears similar technological traits to the Emirian (66, 67). In Arabia, we note the sites of Shi'bat Dihya 1 and 2, which date to the LMP around 55 ka (68, 69). The lithic industries at Wadi Surdud in Yemen, which is ∼2,000 km south of Boker Tachtit, contain a "Levallois-like" industry with unidirectional blades for elongated point production. In this respect, the Wadi Surdud blade technology has some resemblance to the IUP of Boker Tachtit.

All in all, the off-regional hypothesis still needs to be tested by future comparative studies integrating technology and chronology (in high resolution) between the Negev and the Arabia/Nile Valley sites. In addition, the origins of the early IUP populations still need to be discovered.

Conclusions

The earliest dated occupation of the site of Boker Tachtit starts at around 50,000 BP. The lithic industry associated with these early layers is Emirian, and therefore this is the earliest known manifestation of the IUP material culture in western Asia. This overlaps with MP industries from other sites in the region. This shows that local LMP populations coexisted (and probably interacted) with IUP populations in the Negev 50,000 y ago. Notably, the later phase of the IUP overlaps with the EUP Ahmarian assemblages in the northern Mediterranean woodlands. Therefore, these industries could not have been derived from the Negev assemblages.

Materials and Methods

The renewed excavations at Boker Tachtit were conducted in an area of ∼15 m^2 along the edges of the previous excavations (*SI Appendix*, Figs. S4, S5, and S7). A new grid was established and aligned with the former grid set up by Marks (1). The field method included piece plotting of artifacts larger than 2 cm. All sediments were dry sieved using 2-mm mesh. Charcoal samples for dating were handpicked and piece plotted. The mineral compositions of sediment samples were determined using KBr pellets and FTIR spectrometry. Blocks of sediment were embedded and sectioned, and their micromorphology was examined using plain and polarized light in a petrographic microscope (*SI Appendix*, Fig. S1 and S2).

Radiocarbon Chronology. The chronology of Boker Tachtit is based on dates of charcoals prepared by the ABA (Acid-Base-Acid) pretreatment. Before and after pretreatment, samples were analyzed by FTIR spectrometry using KBr pellets to determine the purity of the material. Generally, 30 to 100 mg initial weight of each charcoal sample was cleaned of sediment under a microscope and homogenized by crushing in an agate mortar and pestle. Samples were then treated with the ABA procedure: 1) acid treatment in 1 M HCl for 30 min, followed by rinsing with Nanopure water until the pH reached 6; 2) base treatment of 0.1 M NaOH for 15 min, followed by rinsing until the pH reached 6; and 3) acid treatment in 1 M HCl for 1 h in a water bath of 80 °C, followed by rinsing until the pH reached 6. The NaOH step was sometimes applied more than once if the color of the solution was still dark, indicating the presence of large amounts of humic substances. Samples were dried overnight at ∼60 °C, combusted to CO_2 with ∼200 mg of CuO at 900 °C in a vacuum, and then reduced to graphite in the presence of hydrogen at 680 °C. All samples were measured by AMS at the Dangoor Research Accelerator Mass Spectrometry (D-REAMS) Laboratory (*SI Appendix*, Fig. S4).

Luminescence Dating (OSL). Sediment samples were collected from the newly exposed section (*SI Appendix*, Fig. S15). Three of these samples were from the BG lithostratigraphic unit, and seven were from the underlying SSds. The sediment samples were collected by inserting steel tubes (diameter: 5 cm, length: 20 cm) into the cleaned sections. Both quartz and feldspar were measured on the same granulometric fraction: 40 to 63 μm. The grains were chemically treated with HCl and H_2O_2 in order to remove, respectively, the carbonates and organic materials. Then, the residual fraction was split into two parts. One part was treated with H_2SiF_6 to dissolve the silicates other than quartz. The other part was used for the feldspar measurements. We measured the sample luminescence on two Risø TL-DA-20 readers fitted with calibrated beta sources. We stimulated the quartz minerals using blue LEDs (470 nm) and detected the resulting signals with an EMI 9235QB photomultiplier through a 7.5-mm-thick Hoya U-340 filter. For the feldspar, we used a combination of 870 nm IR diodes and a combination of Schott BG-39 and Schott BG-3 detection filter. The K, U, and Th concentrations were measured using high-resolution gamma spectrometry on the homogenized external part of the tubes for each sample. The external dose rates were calculated from the moisture content (*SI Appendix*, Fig. S5).

Data Availability. All study data are included in the article and/or supporting information.

ACKNOWLEDGMENTS. This project was funded by the Max Planck-Weizmann Center for Integrative Archaeology and Anthropology "Timing of Cultural Changes." The radiocarbon research was also supported by the Exilarch Foundation for the D-REAMS Laboratory. We also acknowledge support from the Department of Human Evolution at the MPI-EVA, the Kimmel Center for Archaeological Science, and the George Schwartzman Fund for the field, laboratory, and material analyses. The excavations at Boker Tachtit were directed by Omry Barzilai and Elisabetta Boaretto (license permits G-53/13; G-38/14; G-29/15). We thank the National Park Authority for their support during the excavation in the Ein Avdat National Park. We thank Ms. Eugenia Mintz for the sample preparation for radiocarbon analysis. We also thank M. Birkenfeld (Israel Antiquities Authority, IAA) and A. Wiegmann (IAA) for the preparation of Figs. 1 and 2. We thank Steffi Hesse for her precious help with luminescence measurements at Max Planck Institute and Sebastien Huot for his advice about fading measurements. E.B. is the incumbent of the Dangoor Professorial Chair of Archaeological Sciences at the Weizmann Institute of Science.

1. P. Mellars, Why did modern human populations disperse from Africa ca. 60,000 years ago? A new model. *Proc. Natl. Acad. Sci. U.S.A.* **103**, 9381–9386 (2006).
2. R. G. Klein, *The Human Career* (University of Chicago Press, 2009).
3. J. J. Hublin, The modern human colonization of western Eurasia: When and where? *Quat. Sci. Rev.* **118**, 194–210 (2015).
4. T. Higham *et al.*, The timing and spatiotemporal patterning of Neanderthal disappearance. *Nature* **512**, 306–309 (2014).
5. L. Excoffier, Human demographic history: Refining the recent African origin model. *Curr. Opin. Genet. Dev.* **12**, 675–682 (2002).
6. R. L. Cann, M. Stoneking, A. C. Wilson, Mitochondrial DNA and human evolution. *Nature* **325**, 31–36 (1987).
7. I. Hershkovitz *et al.*, Levantine cranium from Manot Cave (Israel) foreshadows the first European modern humans. *Nature* **520**, 216–219 (2015).
8. I. Hershkovitz *et al.*, The earliest modern humans outside Africa. *Science* **359**, 456–459 (2018).
9. J.-J. Hublin *et al.*, Initial Upper Palaeolithic *Homo sapiens* from Bacho Kiro cave, Bulgaria. *Nature* **581**, 299–302 (2020).
10. C. J. Bae, K. Douka, M. D. Petraglia, On the origin of modern humans: Asian perspectives. *Science* **358**, eaai9067 (2017).
11. R. Nielsen *et al.*, Tracing the peopling of the world through genomics. *Nature* **541**, 302–310 (2017).
12. K. Harvati *et al.*, Apidima Cave fossils provide earliest evidence of *Homo sapiens* in Eurasia. *Nature* **571**, 500–504 (2019).

13. O. Bar-Yosef, A. Belfer-Cohen, Following Pleistocene road signs of human dispersals across Eurasia. *Quat. Int.* **285**, 30–43 (2013).
14. H. S. Groucutt *et al*., Stone tool assemblages and models for the dispersal of *Homo sapiens* out of Africa. *Quat. Int.* **382**, 8–30 (2015).
15. O. Bar-Yosef, The archaeological framework of the Upper Paleolithic revolution. *Diogenes* **54**, 3–18 (2007).
16. S. L. Kuhn, "In what sense is the Levantine Initial Upper Paleolithic a "transitional" industry" in *The Chronology of the Aurignacian and of the Transitional Technocomplexes*, J. Zilhão, F. D'Errico, Eds. (Instituto Português de Arqueologia Lisboa, 2003), pp. 61–70.
17. A. E. Marks, Comments after four decades of research on the Middle to Upper Paleolithic transition. *Mitteilungen der Gesellschaft für Urgeschichte* **14**, 81–86 (2005).
18. J. M. Tejero *et al*., The osseous industry from Manot Cave (Western Galilee, Israel): Technical and conceptual behaviours of bone and antler exploitation in the Levantine Aurignacian. *Quat. Int.* **403**, 90–106 (2016).
19. F. A. J. Turville-Petre, *Researches in Prehistoric Galilee, 1925-1926* (British School of Archaeology in Jerusalem, 1927).
20. D. A. Garrod, The Mugharet el-Emireh in lower Galilee: Type-station of the Emiran industry. *J. R. Anthropological Institute G. B. Irel.* **85**, 141–162 (1955).
21. L. Copeland, "The Middle and Upper Paleolithic of Lebanon and Syria in the light of recent research" in *Problems in Prehistory: North Africa and the Levant*, F. Wendorf, A. Marks, Eds. (SMU Press, 1975), pp. 317–350.
22. A. E. Marks, "The early Upper Paleolithic: The view from the levant" in *Before Lascaux: The Complex Record of the Early Upper Paleolithic*, R. White, H. Knecht, A. Pike-Tay, Eds. (CRC Press, 1993), pp. 5–21.
23. G. Tostevin, "The Middle to Upper Paleolithic transition from the Levant to Central Europe: In situ development or diffusion?" in *Neanderthals and Modern Humans: Discussing the Transition. Central and Eastern Europe from 50,000-30,000 BP.* J. Orschiedt, G.-C. Weniger, Eds. (Neanderthal Museum, 2000), pp. 90–109.
24. O. Barzilai, N. Gubenko, Rethinking Emireh cave: The lithic technology perspectives. *Quat. Int.* **464**, 92–105 (2018).
25. N. Rebollo *et al*., New radiocarbon dating of the transition from the Middle to the Upper Paleolithic in Kebara cave, Israel. *J. Archaeol. Sci.* **38**, 2424–2433 (2011).
26. L. Meignen, Levantine perspectives on the Middle to Upper Paleolithic "transition." *Archaeology, Ethnology and Anthropology of Eurasia* **40**, 12–21 (2012).
27. K. Douka, C. A. Bergman, R. E. Hedges, F. P. Wesselingh, T. F. Higham, Chronology of Ksar Akil (Lebanon) and implications for the colonization of Europe by anatomically modern humans. *PLoS One* **8**, e72931 (2013).
28. A. E. Marks, J. I. Rose, "A century of research into the origins of the Upper Paleolithic in the Levant" in *Néandertal/Cro-Magnon. La Rencontre*, M. Otte, Ed. (Errance, Arles 2014), pp. 221–266.
29. M. D. Bosch *et al*., New chronology for Ksâr 'Akil (Lebanon) supports Levantine route of modern human dispersal into Europe. *Proc. Natl. Acad. Sci. U.S.A.* **112**, 7683–7688 (2015).
30. B. Alex *et al*., Radiocarbon chronology of Manot cave, Israel and Upper Paleolithic dispersals. *Sci. Adv.* **3**, e1701450 (2017).
31. A. E. Marks, *Prehistory and Paleoenvironments in the Central Negev, Israel: The Avdat/Aqev Area (Vol. 3)* (SMU Press, 1983).
32. P. Volkman, "Boker Tachtit: Core reconstructions" in *Prehistory and Paleoenvironments in the Central Negev, Israel*, A. Marks, Ed. (SMU Press, 1983), pp. 127–190.
33. H. J. Hietala, "Boker Tachtit: Intralevel and interlevel spatial analysis" in *Prehistory and Paleoenvironments in the Central Negev, Israel*, A. Marks, Ed. (SMU Press, 1983), pp. 217–281.
34. A. E. Marks, D. Kaufman, "Boker Tachtit: The artifacts" in *Prehistory and Paleoenvironments in the Central Negev, Israel*, A. Marks, Ed. (SMU Press, 1983), pp. 69–125.
35. Z. Stepka, O. Barzilai, S. Weiner, E. Boaretto, Microflint in archaeological sediments from Boker Tachtit, Israel: A new method for quantifying concentrations of small flint fragments. *J. Archaeol. Sci.* **91**, 52–64 (2018).
36. A. J. Stutz *et al*., Early Upper Paleolithic chronology in the Levant: New ABOx-SC accelerator mass spectrometry results from the Mughr el-Hamamah site, Jordan. *J. Hum. Evol.* **85**, 157–173 (2015).
37. O. Barzilai, E. Boaretto, Boqer Tahtit (Boker Tachtit). *Hadashot Arkheol*. http://hadashot-esi.org.il/report_detail_eng.aspx?id=25116&mag_id=124. Accessed 7 December 2016.
38. P. Goldberg, "Geology of sites Boker and Boker Tachtit and their surroundings" in *Prehistory and Paleoenvironments in the Central Negev, Israel*, A. Marks, Ed. (SMU Press, 1983), pp. 39–61.
39. P. J. Reimer *et al*., The IntCal20 Northern Hemisphere radiocarbon calibration curve (0-55 cal kBP). *Radiocarbon* **62**, 725–758 (2020).
40. T. J. Heaton *et al*., Marine20 the marine radiocarbon age calibration curve (0-55,000 cal BP). *Radiocarbon* **62**, 779–820 (2020).
41. C. Bronk Ramsey, Development of the radiocarbon calibration program OxCal. *Radiocarbon* **43**, 355–363 (2001).
42. G. Guérin, N. Mercier, G. Adamiec, Dose-rate conversion factors: Update. *Anc. TL* **29**, 5–8 (2011).
43. D. W. Zimmerman, Thermoluminescence dating using fine grains from pottery. *Archaeometry* **13**, 29–52 (1971).
44. G. Guérin, N. Mercier, R. Nathan, G. Adamiec, Y. Lefrais, On the use of the infinite matrix assumption and associated concepts: A critical review. *Radiat. Meas.* **47**, 778–785 (2012).
45. A. S. Murray, A. G. Wintle, Luminescence dating of quartz using an improved single-aliquot regenerative-dose protocol. *Radiat. Meas.* **32**, 57–73 (2000).
46. D. J. Huntley, M. Lamothe, Ubiquity of anomalous fading in K-feldspars and the measurement and correction for it in optical dating. *Can. J. Earth Sci.* **38**, 1093–1106 (2001).
47. C. Thiel, J. P. Buylaert, A. S. Murray, N. Elmejdoub, Y. Jedoui, A comparison of TT-OSL and post-IR IRSL dating of coastal deposits on Cap Bon peninsula, north-eastern Tunisia. *Quat. Geochronol.* **10**, 209–217 (2012).
48. G. Guérin *et al*., Absorbed dose, equivalent dose, measured dose rates, and implications for OSL age estimates: Introducing the Average Dose Model. *Quat. Geochronol.* **41**, 163–173 (2017).
49. J. P. Buylaert *et al*., IRSL and post-IR IRSL residual doses recorded in modern dust samples from the Chinese Loess Plateau. *Geochronometria* **38**, 432–440 (2011).
50. M. Jain, A. Murray, L. Bøtter-Jensen, Optically stimulated luminescence dating: How significant is incomplete light exposure in fluvial environments? *Quaternaire* **15**, 143–157 (2004).
51. A. S. Murray, K. J. Thomsen, N. Masuda, J. P. Buylaert, M. Jain, Identifying well-bleached quartz using the different bleaching rates of quartz and feldspar luminescence signals. *Radiat. Meas.* **47**, 688–695 (2012).
52. E. Marks, C. R. Ferring, "The Early Upper Paleolithic of the Levant" in *The Early Upper Paleolithic. Evidence from Europe and the Near East*, J. F. Hoffecker, C. A. Wolf, Eds. (BAR. International Series, 1988), pp. 43–72.
53. S. Kadowaki *et al*., Lithic technology, chronology, and marine shells from Wadi Aghar, southern Jordan, and initial Upper Paleolithic behaviors in the southern inland Levant. *J. Hum. Evol.* **135**, 102646 (2019).
54. G. Guérin, A. S. Murray, M. Jain, K. J. Thomsen, N. Mercier, How confident are we in the chronology of the transition between Howieson's Poort and Still Bay? *J. Hum. Evol.* **64**, 314–317 (2013).
55. S. Kadowaki, "Issues of chronological and geographical distributions of Middle and Upper Palaeolithic cultural variability in the Levant and implications for the learning behavior of Neanderthals and *Homo sapiens*" in *Dynamics of Learning in Neanderthals and Modern Humans*, T. Akazawa, Y. Nishiaki, K. Aoki, Eds. (Springer, 2013), pp. 59–91.
56. M. Goder-Goldberger *et al*., The Middle to Upper Paleolithic transition in the southern Levant: New insights from the Late Middle Paleolithic site of Far'ah II, Israel. *Quat. Sci. Rev.* **237**, 106304 (2020).
57. T. Abulafia, M. Goder-Goldberger, F. Berna, O. Barzilai, O. Marder, A technotypological analysis of the Ahmarian and Levantine Aurignacian assemblages from Manot cave (Area C) and the interrelation with site formation processes. *J. Hum. Evol.*, 10.1016/j.jhevol.2019.102707 (2019).
58. S. Kadowaki, T. Omori, Y. Nishiaki, Variability in Early Ahmarian lithic technology and its implications for the model of a Levantine origin of the Protoaurignacian. *J. Hum. Evol.* **82**, 67–87 (2015).
59. F. C. Munday, "Nahal Aqev (D35): Aa stratified, open-air Mousterian occupation in the Avdat/Aqev area" in *Prehistory and Paleoenvironments in the Central Negev, IsraelPrehistory and Paleoenvironments in the Central Negev, Israel*, A. Marks, Ed. (SMU Press, 1977), pp. 35–-60, vol. 1.
60. H. P. Schwarcz, B. Blackwell, P. Goldberg, A. E. Marks, Uranium series dating of travertine from archaeological sites, Nahal Zin, Israel. *Nature* **277**, 558–560 (1979).
61. O. Barzilai, E. Boaretto, Nahal Aqev (D35). *Hadashot Arkheol*. https://hadashot-esi.org.il/Report_Detail_Eng.aspx?id=25928. Accessed 18 April 2021.
62. A. E. Marks, H. L. Crew, Rosh Ein Mor, an open-air Mousterian site in the central Negev, Israel. *Curr. Anthropol.* **13**, 591–593 (1972).
63. W. J. Rink *et al*., Age of the Middle Palaeolithic site of Rosh Ein mor, central Negev, Israel: Implications for the age range of the early Levantine Mousterian of the Levantine corridor. *J. Archaeol. Sci.* **30**, 195–204 (2003).
64. M. Goder-Goldberger, M. Bar-Matthews, Novel chrono-cultural constraints for the Middle Paleolithic site of Rosh Ein Mor (D15), Israel. *J. Archaeol. Sci. Rep.* **24**, 102–114 (2019).
65. A. E. Marks, K. Monigal, "Modeling the production of elongated blanks from the Early Levantine Mousterian at Rosh Ein Mor" in *The Definition and Interpretation of Levallois Technology*, O. Bar-Yosef, H. Dibble, Eds. (Monographs in World Archaeology 23, Madison, Prehistory Press, 1995), pp. 267–277.
66. P. Van Peer, The Nile corridor and the out-of-Africa model an examination of the archaeological record. *Curr. Anthropol.* **39**, S115–S140 (1998).
67. S. Wurz, P. Van Peer, Out of Africa, the Nile Valley and the Northern route. *South African Archaeological Bulletin* **68**, 168–179 (2012).
68. J. I. Rose, A. E. Marks, Out of Arabia and the Middle-Upper Palaeolithic transition in the southern Levant. *Quartär* **61**, 49–85 (2014).
69. A. Delagnes *et al*., Inland human settlement in southern Arabia 55,000 years ago. New evidence from the Wadi Surdud Middle Paleolithic site complex, western Yemen. *J. Hum. Evol.* **63**, 452–474 (2012).